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MONITORING PERFORMANCE AS A FUNCTION OF MUSCULAR RESPONSE EFFORT

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FOREWORD

The U. S. Army Behavioral Science Research Laboratory is conducting a comprehensive program of research aimed at increasing the effectiveness of human performance, particularly within Army operational systems. One approach is characterized by the experimental study of important behavioral functions with the objective of gaining better understanding of these functions and applying the findings to a number of different systems. This is the approach of the MONITOR PERFORMANCE Task, which deals with the many human, environmental, and situational variables affecting the vigilance of persons performing a broad variety of critical monitoring jobs in the Army. The study reported in the present Technical Research Note explored the effect of requiring muscular effort in responding to signals as a means of attaining more accurate and complete signal detection.

The entire research Task is responsive to special requirements of the U. S. Army Security Agency, as well as to requirements to contribute to achievement of the objectives of RDT&E Project 2J024701A723, Human Performance in Military Systems, FY 1968 Work Program.

J. E. UHLANER, Director
U. S. Army Behavioral Science
Research Laboratory

MONITORING PERFORMANCE AS A FUNCTION OF MUSCULAR RESPONSE EFFORT

BRIEF

Requirement:

To determine whether requiring muscular effort in responding to signals improves monitoring performance, and, if so, to gain an indication of the optimal level of response effort.

Procedure:

Three groups of 16 subjects each stood four 3-hour watches in which the muscular effort required to pull a response handle was varied: 0.5, 6.0, 12.0, and 24.0 pounds. The signal to be detected consisted of a momentary halt of a perturbating pointer on a null meter. Half the subjects were tested in the forenoon, half in the afternoon. Each group was tested under one of three signal frequency levels: 32, 64, and 128 signals per watch.

Findings:

No improvement in performance was found as a function of muscular effort. Subjects tested in the forenoon did significantly worse at the high signal frequency than at the low. Subjects tested in the afternoon showed no change.

Percentage of signals detected and speed of responding were closely related.

Utilization of Findings:

Further attempts to improve signal detection by introducing a requirement for muscular effort in responding are not at present considered likely to be profitable. However, the finding does not preclude the possibility that muscular effort would result in facilitation in other types of monitoring situations, or with other means of inducing muscular tension.

MONITORING PERFORMANCE AS A FUNCTION OF MUSCULAR PESPC'ISE EFFORT

CONTENTS

TABLES

FIGURES

MONITORING PERFORMANCE AS A FUNCTION OF MUSCULAR RESPONSE EFFORT

BACKGROUND AND OBJECTIVES

In the evolution of military weapons and surveillance systems, much of the earlier dependence on operator judgment has been eliminated by automated systems and highly routinized procedures. While monitoring a variety of instrument displays in these new systems, the operator must make fairly simple responses at appropriate times and must continue to respond accurately and quickly when required to work long hours under arduous, fatiguing, or boring conditions. In these systems, the efficiency of the operator is as much a function of his ability to remain alert as of his technical skill (1). Previous studies in the area of vigilance testify to the inefficiency of the human component, particularly during long watches for infrequent, transient, and weak signals (2). The classic decrement function obtained under such conditions is one of decreasing signal detection performance as a function of time on watch. Factors shown to reduce this drop in efficiency include frequent rest periods, supervised monitoring, use of artificial signals, high signal rate and intensity, knowledge of results, and reward and punishment (3). These factors have varying degrees of utility for field application. Most of them are impracticable, tending to emphasize factors which cannot be controlled by systems engineers or military commanders. The present study was a unique attempt to vary the response requirement in a manner directly applicable to monitoring in the field.

Specific Objectives

Specifically, the study was designed to determine 1) whether response-produced muscular effort would contribute to sustained efficiency in monitor performance, and 2) how such effort would interact with the rate at which signals occur and the speed with which they are detected.

METHOD

Variables

Response-produced Muscular Effort. Subjects were required to pull a T-shaped handle each time they detected a signal. Tension on the spring-loaded handle was varied over the following levels: control (0.5 pounds), low (6 pounds), medium (12 pounds), and high (24 pounds). The control level was the minimum effort required to activate the response mechanism. Pilot data indicated that 24 pounds was the highest level that could be tested feasibly without producing muscular fatigue.

Signal Frequency. Low, medium, and high signal rates consisted of 32, 64, and 128 critical signals presented during the three-hour watch.

Time Periods. The continuous three-hour watch was arbitrarily divided into eight equal periods in order to evaluate performance decrements statistically. Previous studies had indicated--and pilot data confirmed--that significant decrements would occur at the low and possibly at the medium signal rate.

Time of Day. Subjects were tested either in the forenoon (from approximately 0800 to 1100 hours) or in the afternoon (from approximately 1230 to 1530 hours).

Days. All subjects were tested for five days, Monday through Friday. The Monday watch served as practice. The four tension levels were administered over the four remaining days according to a counterbalanced design.

Experimental Design

Three independent groups of 16 subjects each were used, one group being assigned to each of the three signal frequencies. Each group was divided into subgroups of eight subjects for each time-of-day condition. The independent subgroups were then tested over four experimental vigils in a repeated measures situation in which day and tension level were systematically counterbalanced in a Latin square design, and each vigil was divided into eight periods. The design is presented schematically in Table 1.

Performance Measures

Percentage of Signals Correctly Detected. A signal was considered to be correctly detected if the subject responded within five seconds after presentation of the signal. Total number of correct detections per period was converted to a percentage score by dividing by the number of signals presented in order to compare performance across groups tested at different signal rates.

Latency of Detection Response. Since recent studies have indicated that response latency, or reaction time, may be a more sensitive index of readiness to respond than is percentage detection (4), a decision was made to include the latency measure of vigilance performance. The interval of time in seconds between presentation of a signal and detection response constituted response latency. The median of the latencies within each period was computed for each subject, thus avoiding the effect of occasional extreme latencies.

Table 1

EXPERIMENTAL DESIGN FOR 16 SUBJECTS TESTED AT THE LOW SIGNAL FREQUENCY[a]

Signal Rate	Time of Day	Sequence	S	Tues. Periods I—VIII	Wed. Periods I—VIII	Thurs. Periods I—VIII	Fri. Periods I—VIII
				Tension Levels			
Low	A.M.	1	1 2	Control	Low	Medium	High
		2	3 4	Low	Control	High	Medium
		3	5 6	Medium	High	Control	Low
		4	7 8	High	Medium	Low	Control
	P.M.	1	9 10	Control	Low	Medium	High
		2	11 12	Low	Control	High	Medium
		3	13 14	Medium	High	Control	Low
		4	15 16	High	Medium	Low	Control

[a]Design repeated at medium and high frequencies.

False Alarms. Responses occurring outside the five-second lockout period were scored as errors of commission, or false alarms. In order to make meaningful comparisons across signal rate conditions, the number of false alarms responses made by each subject per vigil was expressed as a percentage of the total number of responses he made.

Subjects

Ninety-eight enlisted men stationed at Fort Belvoir, Virginia, were tested. None had had previous civilian or military experience on monitor jobs. Fourteen subjects missed one or more days of testing and were dropped from the study. An additional 16 subjects were dropped for falling asleep during one or more watches. Forty-eight subjects were randomly selected from the remaining pool in order to fulfill the requirements of the experimental design. These men were between the ages of 17 and 39 years (median = 20.4) and had a median score of 109.0 on the General Technical Aptitude Area, based on the Verbal and Arithmetic Reasoning tests of the Army Classification Battery. All had normal vision.

Apparatus

The BESRL Vigilometer was utilized in the study[1]. The system consists of four isolated monitor stations which are linked to a solid-state control and recording console. Automatic control of signal characteristics and intersignal intervals is provided by punched paper tape. Response latencies were coded and printed out in hundredths of a second on a digital printer.

The subject sat in front of a console which was located within a well ventilated sound-attenuating booth of the single-wall type. The booth, which is 5 feet wide by 6-1/2 feet high by 8 feet deep (inside dimensions), was maintained at 70° F., and was illuminated by three 100-watt reflector lamps mounted on side walls and directed toward the ceiling. A one-way vision window in the booth door permitted observation of the subject during the watch. The monitor's console is essentially a wide relay rack with a slide-out desk whose upper edge is 30 inches from the floor. Facing the subject above the desk were 24 panels, each 6 by 6 inches, arranged in a 4 (column) by 6 (row) matrix. All panels were blank except for three which contained, one a meter display, one a response handle, and the third an intercom loudspeaker. Reading from bottom up and from left to right, the meter panel was in row 3, column 2; the handle was in row 1, column 3; and the loudspeaker was in row 6, column 1. Four such booths, identically equipped, were located in a room adjacent to the control room so that four subjects could be tested simultaneously. Each subject was tested in the same booth all week, experiencing a different handle tension and meter on each of the four experimental days. The cast aluminum handle was 4.0 inches long and had to be pulled out to the full extent to activate a 6-volt indicator lamp located 1.75 inches above it. Meters and handles were systematically counterbalanced to control for possible meter differences. Subsequent analysis revealed no reliable differences in signal detectability among the meters.

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[1] Description of apparatus adapted from material prepared by Michael Kaplan (5).

Display and Signal Characteristics

The vigilance task consisted of monitoring a 3-inch Weston[2] model 1331 null-type DC microammeter with a 1.8-inch pointer. The dial markings were removed to produce a blank white background. The pointer perturbated plus and minus about 0.25 inches from the vertical null position at a frequency of approximately 160 reversals per minute. The critical signal to be detected consisted of the pointer's halting in the right-hand position for 0.6 second. Thus, the task was one of watching for critical signals in the presence of "noise"--a situation in which maximum decrement would be expected. Pilot data indicated that this critical signal permitted 100 percent detection when the subject was alert and expecting signals.

The signal schedules utilized four intersignal intervals with signals appearing an equal number of times after each interval. The intervals for the three signal rates are presented in Table 2. Although the intervals varied by a factor of 2 across signal rate, the difference among the intervals of a given frequency was a constant 60% of the respective mean intersignal interval. Subjects experienced a different random order of intervals each day.

Procedure

Subjects arrived in groups of eight on Monday morning of each week. They were briefed on the general nature and importance of vigilance research, and an effort was made to enlist their cooperation. The group was then randomly divided into forenoon and afternoon subgroups. While the forenoon subjects experienced a three-hour orientation vigil, the afternoon subgroup was tested on a battery of predictor tests to obtain data for a related BESRL study. In the afternoon, the procedure was reversed.

The testing procedure in the booths was as follows: The four subjects were randomly assigned to the booths when they reported for testing. Elimination needs were satisfied prior to testing, and subjects were told not to leave the booths until the three-hour session was completed. Smoking was allowed. Time pieces were taken from the subjects during the vigil. Instructions (See Appendix A) were read over an intercom to the subjects in their booths. Five signals, spaced about 10 seconds apart, were presented to insure that the apparatus was working. The experimenter then visited each booth to answer questions prior to starting the vigil.

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[2] Trade names are used only in the interest of precision in reporting experimental procedures. Their mention does not constitute indorsement by BESRL or by the Army.

Table 2

DESCRIPTION OF INTERSIGNAL INTERVALS (ISI)

Signal Rate	(Seconds) ISI	(Seconds) Mean ISI	Number of Intervals per Period
	33.80		1
	236.60		1
LOW	439.40	338.00	1
	642.20		1
	16.90		2
	118.30		2
MEDIUM	219.70	169.00	2
	321.10		2
	8.45		4
	59.15		4
HIGH	109.85	84.50	4
	160.55		4

Subjects were told to remain alert, to watch for signals, and to respond to them as quickly as possible by pressing a hand-held response button. They were then to pull the response handle out slowly with the right hand until the indicator light came on, then to release it slowly. Each subject experienced a different level of tension each day, with all four subjects experiencing different levels on a given day. At frequent intervals during the vigil, the experimenter observed the subjects through one-way windows to insure that instructions were being followed.

RESULTS

Signal Detection

Tables 3, 4, and 5 present the mean percentage detection scores and standard deviations for each level of muscular effort and for each period. The means are plotted in Figure 1. Because of heterogeneous error variances, analysis of variance was applied separately to the data for each signal frequency (6). Summaries of all analyses of variance are presented in Appendix B.

Contrary to expectation, no significant facilitation resulted from response effort. Either muscular effort is not a relevant variable for improving monitoring performance, or else the technique used in the present study did not permit the effect to demonstrate itself. It is not inconceivable that handle pulling, regardless of level of effort, quickly became part of the repetitive and boring routine.

Supplementary analyses were conducted to evaluate the effects of signal frequency, time of day, and time periods. Collapsing muscular effort levels, analysis of variance was applied to the signal frequency by time-of-day data (Plotted in Figure 2). Neither of the main effects was significant, and the interaction between them failed to reach the 5 percent level of confidence. In the forenoon condition, however, subjects detected significantly fewer signals under the medium and high signal frequency conditions than under the low frequency ($q = 3.24$ and 4.66, $df = 42$, p's $< .05$ and $.01$, respectively) (7).

The change in performance across time periods was evaluated by the period effect of the main analysis of variance. Only at high signal frequency was this effect significant ($F = 2.80$, $df = 7/56$, $p < .05$). Multiple comparisons indicated that the period effect was due to a significant decline in accuracy among forenoon subjects from period 1 to 5 ($q = 5.31$, $df = 56$, $p < .01$). These performance trends are plotted in Figure 3. The results indicate that subjects tested in the morning not only detected fewer signals overall, but that their performance also deteriorated significantly within the three-hour vigil under the high signal frequency condition. Thus, diurnal rhythm may play an important role in determining the effects of task demands upon monitoring performance.

Table 3

MEAN PERCENTAGE DETECTION AND STANDARD DEVIATIONS OF SUBJECTS
AT LOW SIGNAL FREQUENCY
(Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\overline{\%}$	93.75	84.38	81.25	84.38	87.50	71.88	75.00	84.38	82.71
		SD	10.82	24.80	16.54	17.40	12.50	23.18	25.00	17.40	7.83
	Low	$\overline{\%}$	81.25	84.38	84.38	81.25	87.50	81.25	87.50	78.12	83.20
		SD	20.73	21.42	24.80	24.21	17.68	20.73	21.65	31.72	12.49
	Medium	$\overline{\%}$	96.88	87.50	87.50	87.50	87.50	87.50	96.88	87.50	89.84
		SD	8.27	12.50	12.50	12.50	17.68	12.50	8.27	17.68	6.63
	High	$\overline{\%}$	90.62	93.75	71.88	75.00	84.38	90.62	90.62	90.62	85.94
		SD	17.40	10.82	23.18	25.00	17.40	12.10	12.10	17.40	6.89
		Mean $\overline{\%}$	90.62	87.50	81.25	82.03	86.72	82.81	87.50	85.16	85.45
		$\overline{SD}$	14.30	17.38	19.26	19.78	16.32	17.13	16.76	21.05	8.46
P.M.	Control	$\overline{\%}$	81.25	84.38	81.25	81.25	75.00	71.88	81.25	87.50	80.47
		SD	24.21	17.40	27.24	27.24	27.95	31.72	24.21	12.50	18.43
	Low	$\overline{\%}$	84.38	87.50	84.38	78.12	71.88	78.12	65.62	75.00	78.13
		SD	17.40	17.68	21.42	23.18	26.33	8.27	17.40	21.65	12.16
	Medium	$\overline{\%}$	84.38	78.21	75.00	87.50	78.12	87.50	81.25	75.00	80.86
		SD	17.40	19.52	17.68	12.50	23.18	17.68	20.73	17.68	12.44
	High	$\overline{\%}$	87.50	87.50	90.62	87.50	90.62	78.12	81.25	81.25	85.55
		SD	12.50	17.68	17.40	17.68	12.10	23.18	16.54	20.73	12.93
		Mean $\overline{\%}$	84.38	84.38	82.81	83.59	78.90	78.90	77.34	79.69	81.25
		$\overline{SD}$	17.88	18.07	20.94	20.15	22.39	20.21	19.72	18.14	13.99

Table 4

MEAN PERCENTAGE DETECTION AND STANDARD DEVIATIONS OF SUBJECTS AT MEDIUM SIGNAL FREQUENCY
(Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\bar{\%}$	78.25	76.88	73.75	73.50	86.25	72.00	78.38	73.75	76.59
		SD	16.21	18.09	13.26	15.91	11.50	20.51	21.39	15.84	10.73
	Low	$\bar{\%}$	73.62	78.62	72.12	76.75	64.25	70.62	61.25	72.25	71.16
		SD	17.11	17.36	30.28	21.24	20.18	23.16	14.61	22.23	13.03
	Medium	$\bar{\%}$	84.50	78.38	73.62	59.75	64.12	65.88	56.50	67.38	68.77
		SD	13.54	19.40	24.47	25.75	22.84	17.45	20.88	15.38	14.58
	High	$\bar{\%}$	81.50	73.75	73.62	78.50	75.12	78.25	81.38	78.38	77.56
		SD	10.83	21.96	16.93	13.54	13.98	16.22	15.36	21.39	12.93
	Mean	$\bar{\%}$	79.47	76.91	73.28	72.12	72.44	71.69	69.38	72.94	73.52
		$\overline{SD}$	14.42	19.20	21.24	19.11	17.12	19.34	18.06	18.71	12.82
P.M.	Control	$\bar{\%}$	87.75	89.12	79.75	81.38	86.12	80.00	86.12	89.25	84.94
		SD	15.31	20.98	21.54	17.64	21.84	15.29	13.07	9.73	15.36
	Low	$\bar{\%}$	90.75	76.75	84.50	94.00	90.25	81.50	76.88	79.88	84.19
		SD	10.33	17.17	24.02	6.00	9.73	16.54	21.84	29.83	14.03
	Medium	$\bar{\%}$	81.50	81.62	78.25	78.38	76.88	81.50	67.50	73.75	77.42
		SD	18.67	12.44	13.71	23.21	20.21	20.58	24.03	22.24	13.42
	High	$\bar{\%}$	80.00	75.12	84.62	75.12	86.25	81.50	84.62	90.88	82.27
		SD	15.29	20.80	12.04	24.14	14.61	16.35	17.36	8.18	13.62
	Mean	$\bar{\%}$	85.00	80.65	81.78	82.22	84.62	81.12	78.78	83.44	82.20
		$\overline{SD}$	14.90	17.85	17.83	17.75	16.60	17.19	19.08	17.50	14.11

Table 5

MEAN PERCENTAGE DETECTION AND STANDARD DEVIATIONS OF SUBJECTS AT HIGH SIGNAL FREQUENCY (Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\bar{\%}$	79.25	76.75	74.38	73.62	71.25	65.75	70.50	70.25	72.72
		SD	15.37	13.21	18.82	16.93	17.24	17.59	13.06	17.17	11.49
	Low	$\bar{\%}$	83.12	73.00	72.00	71.25	60.50	72.12	70.50	71.38	71.73
		SD	13.77	13.68	20.51	17.87	16.21	16.92	19.08	14.62	14.19
	Medium	$\bar{\%}$	76.50	72.75	60.25	67.38	68.21	68.75	67.12	66.50	68.42
		SD	15.58	18.05	13.15	20.04	13.30	14.03	19.98	21.12	13.01
	High	$\bar{\%}$	85.38	84.75	72.75	71.25	72.12	72.75	72.88	72.75	75.58
		SD	8.89	6.38	15.34	15.63	19.48	19.06	22.00	11.21	11.08
		Mean $\bar{\%}$	81.06	76.81	69.84	70.88	68.00	69.84	70.25	70.22	72.11
		$\overline{SD}$	13.40	12.83	16.96	17.62	16.56	16.90	18.53	16.03	12.44
P.M.	Control	$\bar{\%}$	87.00	72.88	80.62	84.38	80.75	82.88	90.88	84.62	83.00
		SD	10.06	23.57	13.31	16.56	14.66	17.32	6.99	8.37	12.25
	Low	$\bar{\%}$	87.00	79.75	80.50	75.25	82.25	88.38	82.88	83.50	82.44
		SD	12.41	16.12	9.57	12.63	8.06	9.18	11.55	12.97	7.83
	Medium	$\bar{\%}$	88.38	89.12	83.88	93.25	86.00	83.75	82.25	86.12	86.59
		SD	13.87	8.78	14.70	4.68	11.14	15.94	14.25	11.93	8.79
	High	$\bar{\%}$	94.75	91.50	90.00	88.62	85.50	87.75	89.25	81.38	88.59
		SD	5.56	12.00	10.28	10.45	13.80	17.07	8.76	12.44	8.15
		Mean $\bar{\%}$	89.28	83.31	83.75	85.38	83.62	85.69	86.32	83.90	85.16
		$\overline{SD}$	10.48	16.37	11.96	11.08	11.92	14.88	10.39	11.43	9.26

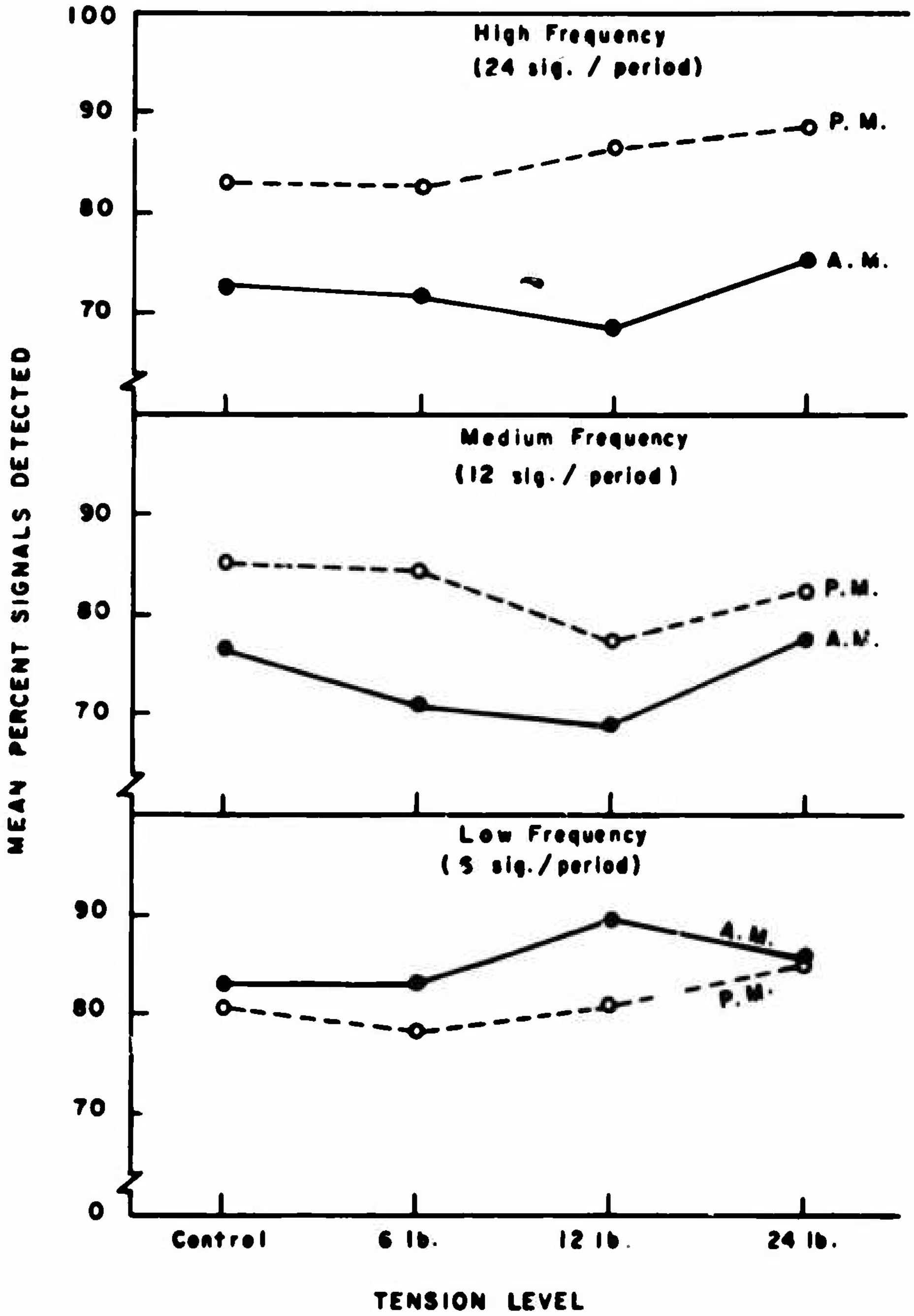

Figure 1 Mean percent of signals detected as a function of tension level by signal frequency (Ns = 8)

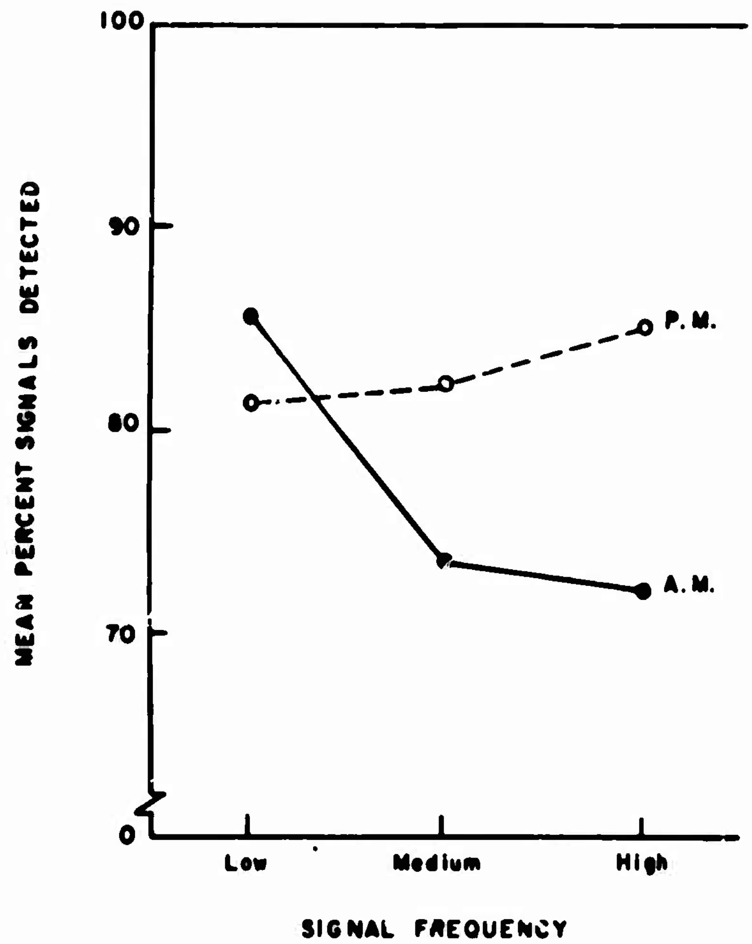

Figure 2. Mean percent signals detected as a function of signal frequency by time of day (Ns = 32)

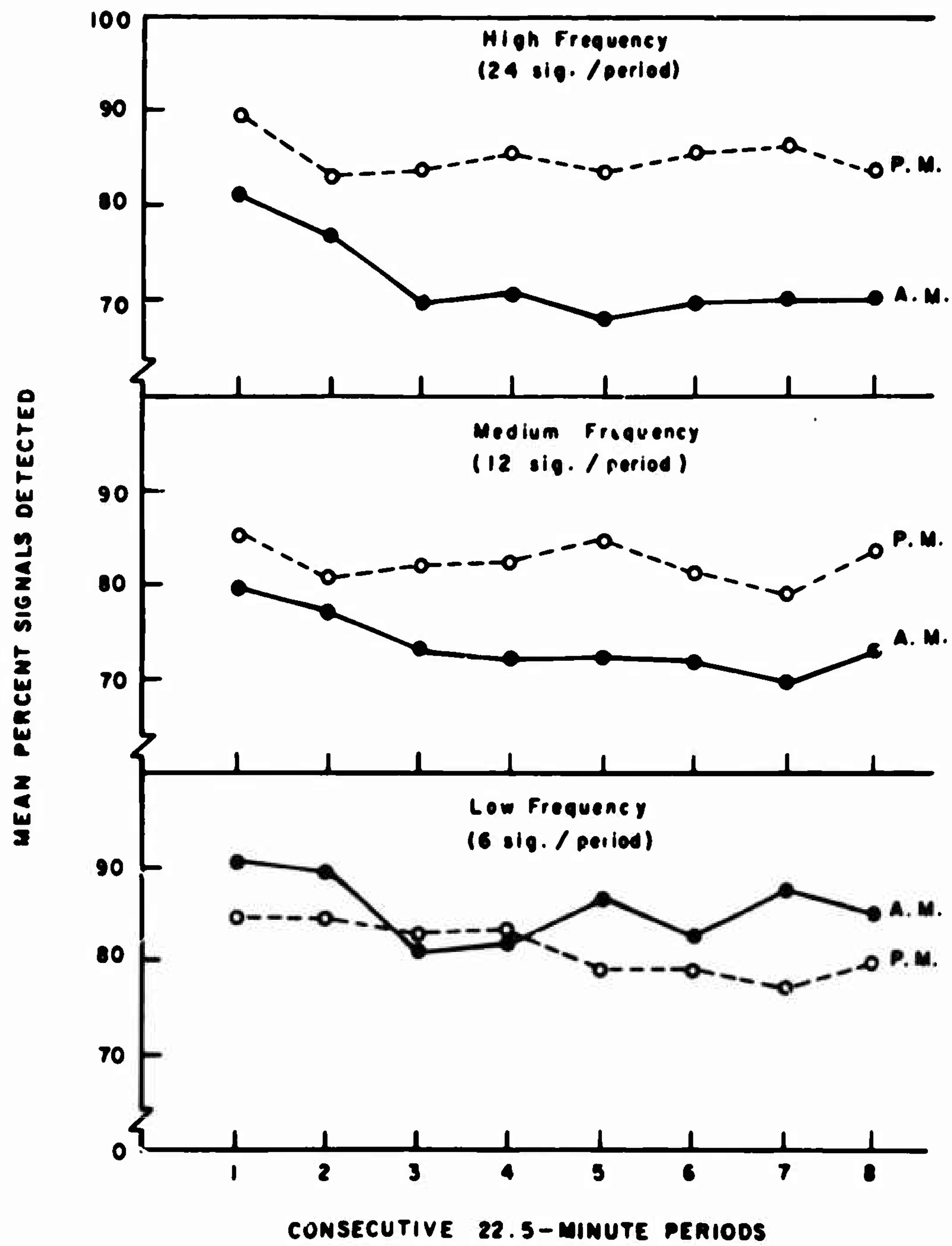

Figure 3. Mean percent signals detected as a function of period by signal frequency (Ns = 8)

Response Latency

Latency scores were analyzed identically to the percentage measures, with similar results. The mean latency scores and standard deviations are presented in Tables 6, 7, and 8, and the tension means are plotted in Figure 4. The analysis of variance again indicated no significant facilitative effect from the muscular effort variable; consequently, effort was dropped as a variable. Supplementary analyses again indicated superior performance for afternoon subjects at high signal frequency ($q = 13.36$, $df = 1/8$, $p < .01$). However, no significant differences among signal frequency conditions were obtained (Figure 5).

The degree of relationship between the two dependent variables was ascertained using each subject's mean score across periods and vigils. The obtained Pearson coefficients of correlation are presented in Table 9, which shows that high agreement prevailed under all three signal frequencies.

False Alarms

Subjects typically made few errors of commission (false alarms), which were unrelated to period or tension level. A mean percentage false alarms index was therefore computed for each subject by averaging across tension conditions. The medians of these individual measures are presented in Table 10. Using Mann-Whitney U tests, the afternoon group was found to have proportionately more false alarms at the low frequency than at the high ($U = 2$, $p = .036$). The difference between forenoon and afternoon groups at low frequency was not significant ($U = 17$, $p = .13$). False alarms measures were uncorrelated with either percentage detection or latency scores.

CONCLUSIONS

The present study was an exploratory attempt to determine whether improvement in monitoring performance could be obtained by requiring muscular effort in responding to signals. Failure to obtain a facilitation under four levels of muscular effort at two different times of day does not preclude the possibility that other forms of muscular involvement would serve such a function.

Table 6

RESPONSE LATENCY DATA FOR LOW SIGNAL FREQUENCY IN SECONDS
(Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\overline{RT}$	1.00	1.00	1.03	1.04	1.04	1.13	1.11	1.03	1.05
		SD	.26	.27	.23	.22	.21	.34	.24	.26	.21
	Low	$\overline{RT}$	.95	1.03	1.10	1.05	1.07	1.04	1.08	.99	1.04
		SD	.13	.21	.16	.25	.18	.08	.27	.15	.14
	Medium	$\overline{RT}$	.93	1.06	1.01	1.04	1.02	.99	1.02	1.19	1.03
		SD	.12	.14	.17	.08	.17	.15	.13	.38	.10
	High	$\overline{RT}$	1.06	1.13	1.14	1.10	1.06	1.09	1.11	1.03	1.09
		SD	.27	.16	.25	.18	.13	.13	.13	.17	.14
	Mean	$\overline{RT}$	.99	1.05	1.07	1.06	1.05	1.06	1.08	1.06	1.05
		SD	.19	.20	.20	.18	.17	.17	.19	.24	.14
P.M.	Control	$\overline{RT}$	1.10	1.21	1.17	1.19	1.16	1.17	1.10	1.18	1.16
		SD	.32	.34	.38	.29	.21	.26	.25	.19	.26
	Low	$\overline{RT}$	1.12	1.15	1.12	1.24	1.14	1.07	1.09	1.06	1.12
		SD	.42	.36	.31	.39	.24	.23	.30	.30	.30
	Medium	$\overline{RT}$	1.04	1.12	1.22	1.08	1.18	1.19	1.08	1.30	1.15
		SD	.37	.33	.25	.24	.22	.34	.30	.35	.25
	High	$\overline{RT}$	1.02	1.17	1.02	1.05	1.04	1.09	1.08	1.14	1.08
		SD	.28	.27	.33	.32	.17	.23	.18	.29	.24
	Mean	$\overline{RT}$	1.07	1.16	1.13	1.14	1.13	1.13	1.09	1.17	1.13
		SD	.35	.33	.32	.31	.21	.26	.26	.28	.26

Table 7

RESPONSE LATENCY DATA FOR MEDIUM SIGNAL FREQUENCY IN SECONDS
(Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\overline{RT}$	1.06	1.02	1.16	1.13	1.11	1.15	1.08	1.13	1.10
		SD	.27	.18	..25	.31	.23	.29	.16	.24	.20
	Low	$\overline{RT}$	.99	1.22	1.08	1.12	1.07	1.10	1.13	1.06	1.10
		SD	.18	.34	.23	.24	.21	.23	.09	.20	.20
	Medium	$\overline{RT}$	1.10	1.17	1.18	1.09	1.26	1.16	1.17	1.16	1.16
		SD	.16	.30	.28	.19	.26	.27	.20	.18	.22
	High	$\overline{RT}$	.92	1.05	1.06	1.10	1.10	1.10	1.10	1.10	1.07
		SD	.13	.12	.15	.19	.20	.30	.20	.18	.16
	Mean	$\overline{RT}$	1.02	1.12	1.12	1.11	1.14	1.13	1.12	1.11	1.11
		SD	.19	.23	.23	.23	.23	.27	.16	.20	.20
P.M.	Control	$\overline{RT}$	1.09	1.07	1.18	1.11	1.10	1.14	1.12	1.12	1.12
		SD	.37	.33	.26	.30	.31	.25	.32	.34	.31
	Low	$\overline{RT}$	.99	1.15	1.04	1.15	1.06	1.02	1.12	1.20	1.09
		SD	.28	.13	.18	.33	.23	.20	.29	.26	.20
	Medium	$\overline{RT}$	1.05	1.07	1.10	1.17	1.16	1.04	1.08	1.14	1.10
		SD	.30	.24	.36	.34	.30	.21	.24	.41	.30
	High	$\overline{RT}$	.97	1.04	1.13	1.10	1.13	1.07	1.05	1.07	1.07
		SD	.17	.33	.30	.26	.32	.33	.29	.30	.28
	Mean	$\overline{RT}$	1.03	1.08	1.11	1.13	1.11	1.07	1.10	1.13	1.10
		SD	.28	.26	.28	.31	.29	.25	.28	.33	.27

Table 8

RESPONSE LATENCY DATA FOR HIGH SIGNAL FREQUENCY IN SECONDS
(Ns = 8)

Time of Day	Tension Level		Period 1	2	3	4	5	6	7	8	Overall
A.M.	Control	$\overline{RT}$	1.06	1.13	1.12	1.18	1.16	1.14	1.16	1.13	1.14
		SD	.27	.23	.21	.22	.18	.19	.20	.12	.18
	Low	$\overline{RT}$	1.04	1.11	1.08	1.12	1.07	1.11	1.12	1.13	1.10
		SD	.22	.20	.14	.14	.14	.16	.17	.12	.14
	Medium	$\overline{RT}$	1.10	1.11	1.13	1.17	1.12	1.13	1.11	1.15	1.13
		SD	.23	.24	.22	.19	.21	.16	.20	.18	.20
	High	$\overline{RT}$	1.11	1.06	1.19	1.13	1.14	1.21	1.15	1.17	1.15
		SD	.26	.17	.22	.19	.16	.18	.19	.19	.18
	Mean	$\overline{RT}$	1.08	1.10	1.13	1.15	1.12	1.15	1.14	1.14	1.13
		SD	.24	.21	.20	.19	.17	.17	.19	.15	.17
P.M.	Control	$\overline{RT}$	.90	.99	.88	.95	.97	.92	.98	.94	.94
		SD	.08	.16	.09	.15	.16	.08	.16	.12	.12
	Low	$\overline{RT}$	.93	1.02	.97	1.03	.94	.95	.96	.94	.97
		SD	.05	.14	.13	.14	.12	.12	.16	.17	.10
	Medium	$\overline{RT}$	.98	.97	.96	1.00	1.00	.97	1.00	.98	.98
		SD	.14	.11	.07	.12	.09	.13	.16	.10	.09
	High	$\overline{RT}$	.92	.98	.96	.95	1.00	.94	.98	.88	.95
		SD	.15	.17	.16	.15	.19	.12	.15	.12	.14
	Mean	$\overline{RT}$	.93	.99	.94	.98	.98	.94	.98	.93	.96
		SD	.11	.14	.11	.14	.14	.11	.16	.13	.11

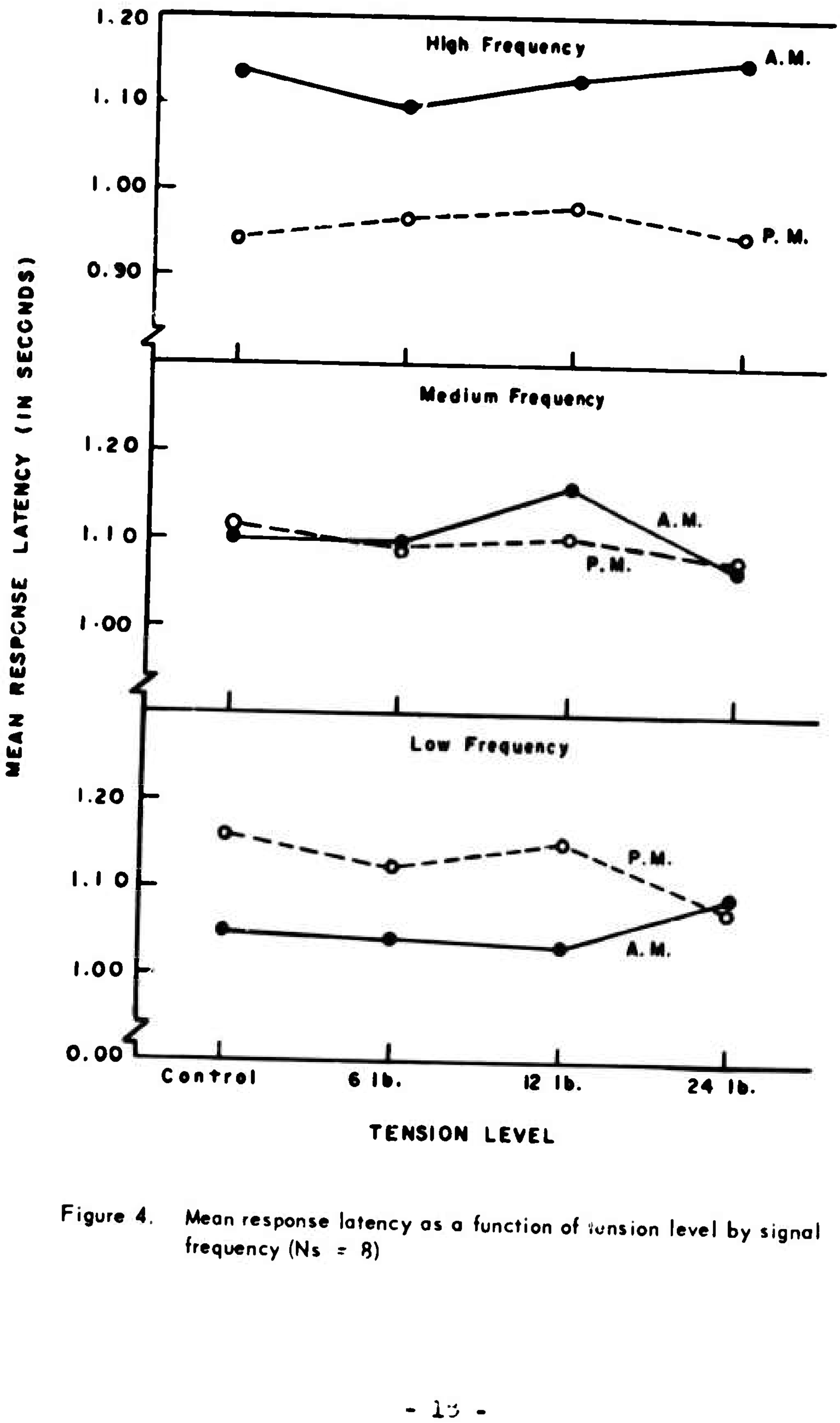

Figure 4. Mean response latency as a function of tension level by signal frequency (Ns = 8)

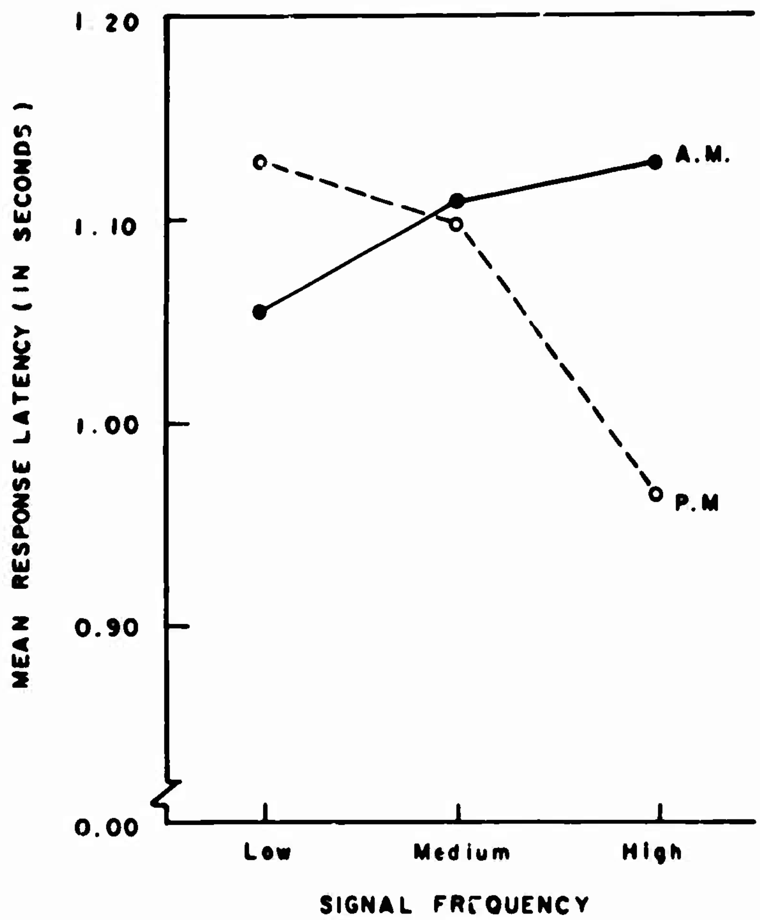

Figure 5. Mean response latency as a function of signal frequency by time of day (Ns = 32)

Table 9

CORRELATION BETWEEN LATENCY AND PERCENTAGE DETECTION MEASURES

Signal Rate	r	N	P
Low	-.73	16	.005
Medium	-.51	16	.05
High	-.73	16	.005
Mean	-.67		.01

Table 10

MEDIAN NUMBERS OF FALSE ALARMS AND RANGE FOR ALL SUBJECTS

Signal Rate	Time-of-Day Condition			
	A.M.		P.M.	
	Median	Range	Median	Range
Low	0.39	0 - 5.05	3.02	0.88 - 5.48
Medium	0.47	0 - 4.08	1.98	0 - 8.00
High	0.88	0 - 2.92	0.48	0 - 6.82

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APPENDIXES

APPENDIX A INSTRUCTIONS TO SUBJECTS

PRACTICE SESSION

"Attention men! In front of you is a rectangular meter. Occasionally the pointer on this meter will halt in the right-hand position briefly. Watch carefully (signal is demonstrated). This is called a signal. Whenever you see this happen, report it as quickly as possible by pressing the button. Hold the response button in your hand at all times and press it firmly only once each time you see a signal.

"Your job is to detect and report as many signals as you can, but do not respond unless you actually see a signal. The signals will occur very infrequently and they will be brief--so you must remain alert and watch for them. Do not leave your seat, and do not go to sleep. This is very important. You may smoke if you wish. Do not tamper with or touch the apparatus or lights.

"A demonstration will now be given. Watch the meter and respond as soon as you detect the signals. (10 signals are presented) Good! Remember that signals will occur at a much slower rate during the actual experimental session.

"Now I will visit each station to answer any questions before we begin the experiment. (Visit and close booth doors.)

"We will now begin the experimental session. You will be told when the experiment is over for today. Remember, stay alert and watch the meter. You will be observed through the one-way window from time to time.

"Standby to begin."

TENSION CONDITIONS

"Attention men! In this session your detection task will be the same as last: every time you detect a signal, report it by pressing the button as quickly as possible. During this session you are to pull the response handle in front of you after pressing the button. Pull the lever with your right hand until the red light comes on and then release it. Pull it only once each time you detect a signal, and do not hold on to it or play with it between signals. Remember to press the button before you pull the lever. Hold the button in your left hand at all times.

"I will again give you a demonstration of what the signal looks like. Press the button and then pull the lever as soon as you detect the signals. (5 signals are presented) Good! Now I will visit each station to make sure you understand what to do. (Visit and close booth doors.)

"We will now begin the experimental session. Remember, stay alert and watch the meter. Do not stand up or walk around, and do not go to sleep. You will be observed through the window from time to time.

"Standby to begin."

APPENDIX B

SUMMARIES OF ANALYSES OF VARIANCE

Table B-1

SUMMARY OF ANALYSIS OF VARIANCE OF DETECTION SCORES ACROSS EXPERIMENTAL CONDITIONS

Source of Variance	df	Signal Frequency					
		Low		Medium		High	
		MS	F	MS	F	MS	F
Time of Day (T)	1	2257	.80	9652	2.00	21772	11.10*
Sequence (S)	3	3572	1.26	8408	.58	8008	4.08*
T x S	3	2563	.90	5006	1.03	1103	.56
Subjects	8	2831		4839		1961	
Day (D)	3	939	1.94	175	.35	1078	4.07*
Tension (C)	3	848	1.75	1511	3.04*	690	2.60
(D x C)'	6	301	.62	568	1.14	272	1.02
D x T	3	1460	3.02*	326	.66	73	.28
C x T	3	444	.92	372	.75	420	1.58
T(D x C)'	6	161	.33	491	.99	72	.27
D x Subjects	24	484		497		265	
Period (P)	7	312	.84	343	1.08	546	2.80*
P x T	7	279	.75	120	.38	213	1.09
P x S	21	593	1.60	259	.82	224	1.15
P x S x T	21	243	.66	211	.67	149	.77
P x Subjects	56	370		316		195	
P x D	21	352	1.08	169	.74	181	1.36
P x C	21	224	.69	368	1.60	134	1.01
P(D x C)'	42	235	.72	188	.82	158	1.19
P x D x T	21	207	.64	151	.66	126	.95
P x C x T	21	300	.92	188	.82	108	.81
T x P(D x C)'	42	422	1.30	317	1.38	98	.74
P x D x Subjects	168	326		229		132	
Total	511						

*p < .05

Table B-2

SUMMARY OF ANALYSIS OF VARIANCE ON PERCENTAGE DETECTION SCORES ACROSS SIGNAL FREQUENCIES

Source of Variance	df	MS	F
Signal Frequency (F)	2	141.2	1.30
A.M. Linear Trend	1	711.8	6.54**
P.M. Linear Trend	1	61.2	.56
Time of Day (T)	1	409.7	3.77*
F x T	2	321.6	2.96*
Within Error	42	108.8	

*$p < .10$
**$p < .05$

Table B-3

SUMMARY OF ANALYSIS OF VARIANCE OF LATENCY SCORES ACROSS EXPERIMENTAL CONDITIONS

Source of Variance	df	Signal Frequency: Low MS	Low F	Medium MS	Medium F	High MS	High F
Time of Day (T)	1	.711	.83	.018	.01	3.538	13.36**
Sequence (S)	3	2.483	2.89	.980	.67	1.618	6.11*
T x S	3	.453	.53	2.524	1.73	.372	1.41
Subjects	8	.860		1.460		.265	
Day (D)	3	.051	.37	.012	.16	.038	1.81
Tension (C)	3	.013	.10	.090	1.23	.014	.65
(D x C)'	6	.125	.92	.107	1.47	.066	3.11*
D x T	3	.006	.04	.024	.33	.096	4.50*
C x T	3	.118	.86	.034	.47	.037	1.72
T(D x C)'	6	.093	.68	.134	1.84	.042	2.00
D x Subjects	24	.137		.073		.021	
Period (P)	7	.047	1.34	.071	2.49*	.022	1.38
P x T	7	.017	.48	.013	.47	.016	1.05
P x S	21	.024	.68	.028	1.00	.011	.70
P x S x T	21	.045	1.31	.034	1.19	.015	.96
P x Subjects	56	.035		.029		.016	
P x D	21	.048	1.58	.016	.76	.008	.73
P x C	21	.032	1.05	.029	1.34	.008	.74
P(D x C)'	42	.044	1.47	.022	1.05	.011	.98
P x D x T	21	.029	.96	.022	1.04	.008	.75
P x C x T	21	.019	.64	.011	.53	.005	.41
T x P(D x D)'	42	.025	.84	.015	.72	.011	.94
P x D x Subjects	168	.030		.021		.011	
Total	511						

$*p < .05$
$**p < .01$

Table B-4

SUMMARY OF ANALYSIS OF VARIANCE ON RESPONSE LATENCY SCORES ACROSS SIGNAL FREQUENCIES

Source of Variance	df	MS	F
Signal Frequency (F)	2	.015	.43
A.M. Linear Trend	1	.022	.66
P.M. Linear Trend	1	.110	3.22*
Time of Day (T)	1	.014	.43
F x T	2	.060	1.74
Within Error	42	.034	

*$p < .10$

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13. ABSTRACT

An exploratory study to determine the effect of requiring muscular effort in responding to signals as a means of improving monitoring performance is described. Results of previous studies in the area of vigilance, conducted by the MONITOR PERFORMANCE Task, BESRL and other investigators, testify to decrement in performance as a function of time on vigil, signal rate and intensity, and fatiguing or monotonous task conditions. Specifically, the present study was designed to determine 1) whether response requiring muscular effort would contribute to sustained efficiency in monitor performance, and 2) how such effort would interact with signal frequency. In the experimental procedure, three groups of 16 subjects each stood four 3-hour watches in which the muscular effort required to pull a spring-loaded response handle was varied over four levels: control (0.5 lbs.), low (6 lbs.), medium (12 lbs), and high (24 lbs.). Each group was tested under one of three signal frequency levels--32, 64, and 128 critical signals per watch. The critical signal to be detected consisted of a 0.6-second halt of a perturbating pointer on a null meter.

Performance was statistically evaluated for correct detections per period, response latency (reaction time), and false alarms (errors of commission). Results showed no improvement was attained in performance as a function of muscular effort. Subjects tested in the forenoon detected fewer signals as a function of increasing signal frequency and deteriorated significantly in performance under the high signal frequency level. Subjects tested in the afternoon showed no change. Analyses also indicated close correlation between percentage detection and latency scores; neither was correlated

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	ROLE	WT	ROLE	WT	ROLE	WT
*Monitor performance						
*Signal detection performance						
*Psychophysical variable--monitoring						
*Muscular response effort						
Induced muscular tension						
Laboratory facilities						
*Decrement function						
Reaction time						
*Response latency						
Vigilance task						
Experimental procedures						

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13. ABSTRACT continued

with false alarms measures. The analysis indicates that little or no gain in monitor performance efficiency would be expected from a requirement for muscular effort in responding to signals. The finding does not preclude, however, the possibility that muscular effort would result in facilitation in other types of monitoring situations, or with other means of inducing muscular tension.